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(NASA-TM-X-73966) NASA OFFICE OF AERONAUTICAL AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 6: STRUCTURES AND DYNAMICS PANEL Final Report (NASA) 93 p HC A05/MF A01 CSCL 13M G3/85

N77-13915

Unclas
56956

STRUCTURES and DYNAMICS

OAST Summer Workshop

OAST ODU 1975

National Aeronautics
and Space Administration
Office of Aeronautics and Space
Technology and Old Dominion University

OLD DOMINION UNIVERSITY 1930

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Vol. VI of XI

NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 - 15, 1975 are contained in the following reports:

EXECUTIVE SUMMARY

VOL I DATA PROCESSING AND TRANSFER

VOL II SENSING AND DATA ACQUISITION

VOL III NAVIGATION, GUIDANCE, AND CONTROL

VOL IV POWER

VOL V PROPULSION

VOL VI STRUCTURE AND DYNAMICS

VOL VII MATERIALS

VOL VIII THERMAL CONTROL

VOL IX ENTRY

VOL X BASIC RESEARCH

VOL XI LIFE SUPPORT

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NASA

Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

Final Report

STRUCTURES AND DYNAMICS PANEL

Volume VI of XI

OAST Space Technology Workshop

STRUCTURES AND DYNAMICS PANEL

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INTRODUCTION

This document contains the results of the Structures and Dynamics Technology Group working sessions. The prime objective of the group was to identify the structures and dyanmics technology areas that need to be developed in order to carry out future activities in space. The areas were identified as mission driven or opportunity driven. Also identified were areas where utilization of the STS for experimentation in space could significantly enhance the development of the technology.

The technology areas identified correspond to the titles of the sections following the summary. Each section includes a page describing the objectives of the technology area, the scope, justification, and approach. In each section also are technology requirement forms and future testing and development requirement forms.

SUMMARY

The procedure used to define the structural requirements, technology needs and payloads is shown schematically in Figure 1. The objectives and missions in the OFS study were examined and critical missions requiring structures and dynamics technology determined. The 1973 Mission Model was used to provide additional input. Once the critical missions were known, the structural requirements for these missions were identified. Other technology panels and users were then consulted to determine if any critical missions or structural requirements were omitted. Technology areas, technical tasks, ground evaluation and payload definition were then defined for each structural requirement.

The working group also examined present and future research developed along disciplinary lines and forecast those technology improvements that could provide opportunities to either perform missions now impossible or more efficiently. Technology areas that meet this criteria were referred to as opportunity driven technology.

The principal technology driver for most missions and objectives was found to be Large Area Space Structures (LASS). Three categories of LASS were identified: antennas, solar array structures and platforms. Figure 2 shows examples of these while Figure 3 shows the size and accuracy of antenna structures required in communications, earth observations and power transmission. One of the largest structures required is a solar array for a solar power station whose total area is 50 square kilometers. In addition to large area structures, several missions required a long, slender structure or boom. This type of structure would be used either to support large objects from the shuttle or hold two bodies apart in space. Astronomy (OSS) has the most stringent requirement for such a structure; the maintaining of two bodies 100 - 1000 meters apart with an accuracy of one centimeter and a knowledge of their position to ten microns.

The opportunity driven technology needs consisted of advanced composite structure including minimum gage concepts and high temperature components, load and response determination and control, and reliability and life predictor. Advanced composites are needed by future space transportation systems and payloads for cost-effective weight reductions. Due to the high cost and weight sensitivities of spacecraft, accurate and reliable life prediction are mandatory.

The principal conclusion of the Structures and Dynamics Technology groups was that the most critical structural requirement for the achievement of the important objective of OFS is the timely development of large erectable space structures. Three major thrusts needed to accomplish this task were defined.

1. Develop and verify erectable structures technology for large (1 km) space structures by 1985.

2. Develop composites technology to provide a weight savings of 30% to 50% in LASS.

3. Experiments to verify erection techniques for large structures in orbit.

The LASS technology needs were divided into six general categories.
(1.) For the short term, large **aperture** deployable antenna structures have to be developed. This technology will be applicable to currently planned mission in which relatively small size structures are required. For larger structures, erectable concepts are needed. In order to provide the technology for erectable structures, efforts in several technology areas must be initiated.
(2.) Erectable structures concepts must be defined. This includes: the development of basic structural elements or building blocks that can be efficiently packaged into the Shuttle blocks that can be efficiently packaged into the Shuttle bay, determination of the configurations that result in the most effective assembly of the building blocks, and development of methods of assembly and fabrication in space.
(3.) Techniques for actively controlling ans stiffening the structure must be developed to achieve the high precision needed for effective use of antenna structures.
(4.) Thermal distortion free structural concepts must be developed through the use of materials, designs, fabrication, and control techniques that will achieve structural assemblies that are dimensionally insensitive to change in the thermal environment.
(5.) The feasibility of integrated systems concepts in which component elements of the structure and system perform multidisciplinary functions of structure, thermal control, and electrical conduction must be evaluated.
(6.) Improved analytical procedures have to be developed that will permit the integration of all subsystem analyses so that interactions between subsystems can be accurately evaluated and trade-off studies can be performed.

The payload description of the LASS of necessity is general in content. The technologies are entirely new so that a considerable amount of structural system studies, analyses, and ground tests are needed to define the limits of technologies, the specific configurations of interest, and verification tests required.

The following in-space tests are essential to developing technology to meet the needs for future space activities:

1.) Large aperture deployable antenna structure demonstration.

2.) Prototype large space structural element

3.) Large erectable space structure - system development test

4.) Actively controlled/stiffened structure feasibility test

other important tests are

5.) Thermal-distortion-free structures demonstration

6.) High-Temperature Polyimide Composite Shuttle Flight Experiment

7.) High-Temperature Metal Matrix Composite Shuttle Flight Experiment

8.) Long slender space structure

9.) Space application of non-distructive evaluation

10.) In-space development of inspection process

11.) Shuttle bay dynamic environment measurement

12.) Shuttle orbiter load alleviation experiment

STRUCTURES AND DYNAMICS WORKING GROUP - APPROACH

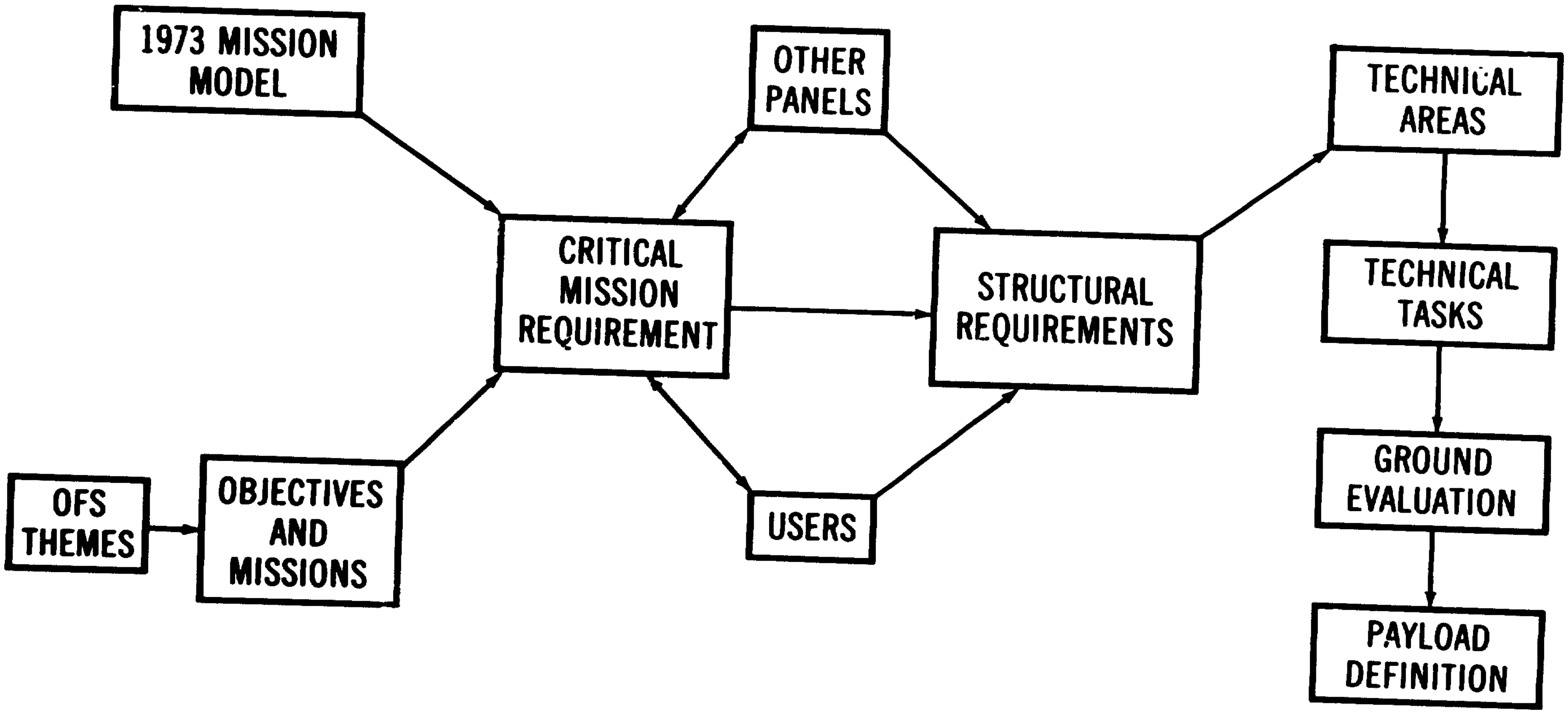

Figure 1

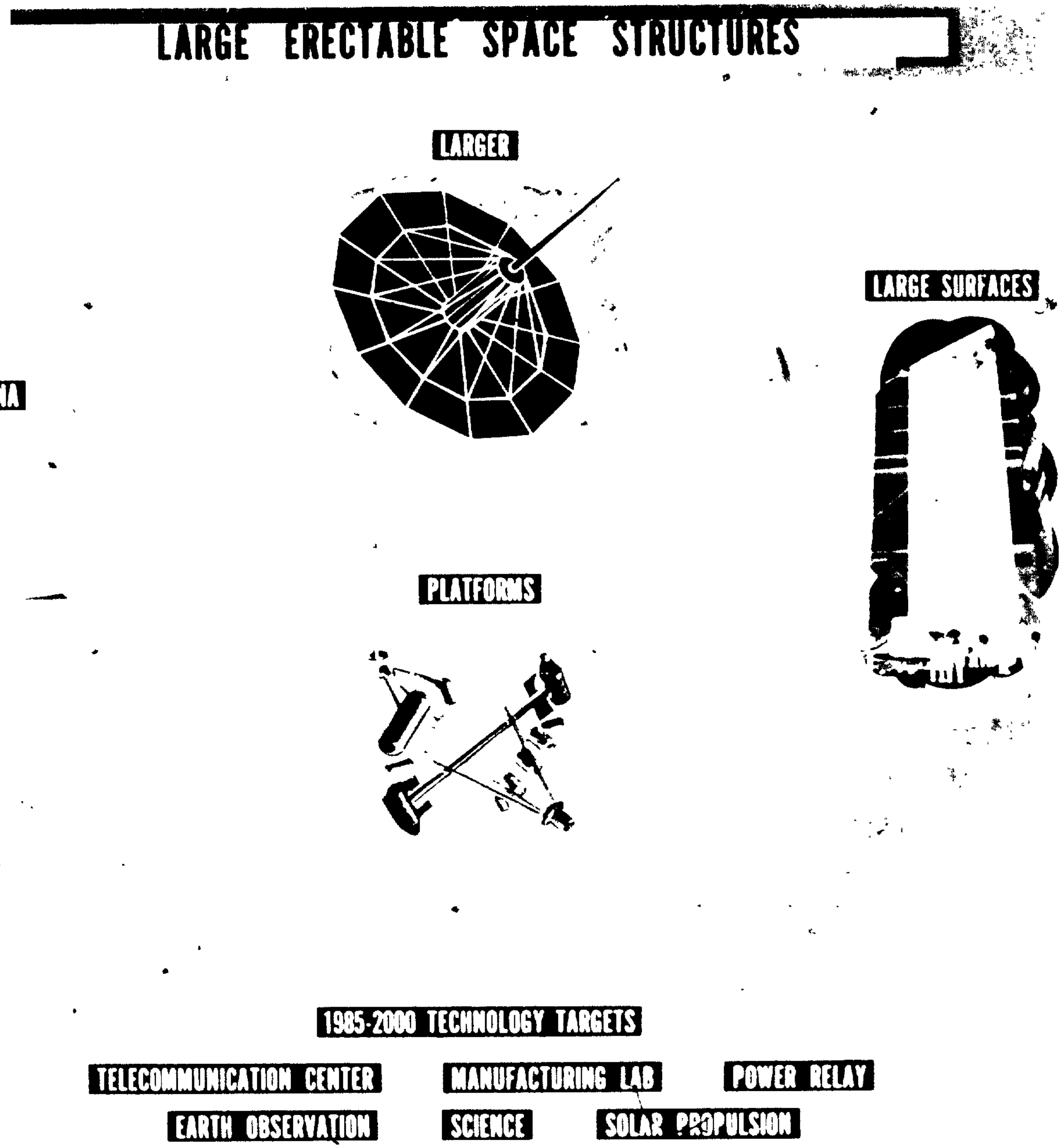
LARGE ERECTABLE SPACE STRUCTURES
LARGER
ANTENNA
LARGE SURFACES
PLATFORMS
1985-2000 TECHNOLOGY TARGETS
TELECOMMUNICATION CENTER
MANUFACTURING LAB
POWER RELAY
EARTH OBSERVATION
SCIENCE
SOLAR PROPULSION

Figure 2

FUTURE COMMUNICATIONS AND EARTH OBSERVATION TECHNOLOGIES NEED LARGER ANTENNAS

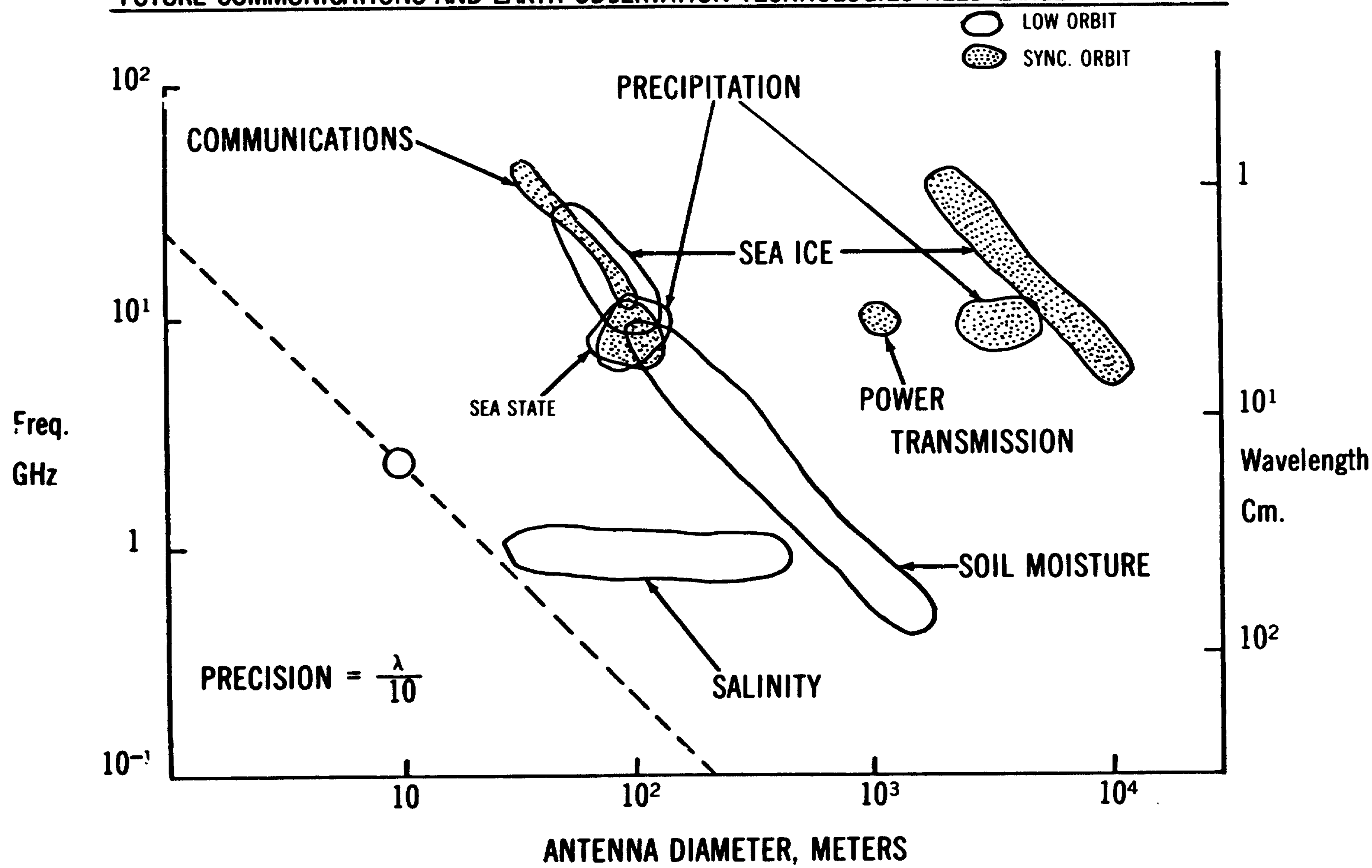

Figure 3

TABLE OF CONTENTS

LARGE, DEPLOYABLE SPACE STRUCTURES

I. Title:

Large-Aperture Deployable Antenna Structures

II. Objectives:

Achieve technology readiness by 1983 for 100 meter diameter microwave antennas, two to 20 cm wavelength, to be furled in a single package in the shuttle and demonstrate operation in earth orbit by a shuttle flight structural experiment.

III. Scope and Justification:

Earth observation and communication satellites, themes 02 through 05 of OFS, for the 1885-2000 period require large-aperture, space-borne antennas of at least 100 meters in diameter with a surface accuracy of one mm rms (1/10 to 1/16 of a save length) for radio frequency operation in the cm wavelengths (L to K-band).

Present technology can produce space-borne deployable antennas up to 10 meters in diameter with a surface accuracy of about 3 mm (rms), as represented by the operation ATS-6 satellite. Development work in progress is expected to extend the state-of-the-art to about 15 meters with a one mm surface accuracy, as evidenced by the work carried out on 4 to 5 meter prototpye parabolic and conical reflectors (Lockheed, Harris, JPL).

The major goal associated with large aperture microwave antennas is to maintain the high degree of surface accuracy when size is increased, since the deviation from the desired surface increases with size.

There exists at the present time two known types of mico-wave antennas (1.) the reflector(s) with a single radio frequency (RF) source and (2.) the flat array made of a large number of dipoles connected to an equal number of phased RF sources. This last type, the array, presents significant potential advantages for electronic operation, hence it is receiving increasing attention for microwave mapping and communication. One can then assume that large aperture microwave antennas of the 1985-2000 period will most likely require both types i.e., the reflector and the array.

Type 1 - Reflector

This is the cost advanced type. However, it is not antici-pated that direct extrapolation of the present state-of-the-art, one mm accuracy for a 15 meter size, will meet the 1985-2000 requirements of one mm accuracy for 100 meter size. New methods to maintain the surface accuracy for the large size will have to be developed such as an in-flight automatic adjustment of reflector shape (active shape control).

Type 2 - Array

The array antenna technology is much less advanced than that of the reflectors and will require a considerable amount of development to meet the 1985-2000 requirement. It should be noted that the technology available for solar arrays, developed for the use of solar cells, does not provide the degree of accuracy needed (one mm) for the dipole location that the array antenna needs. New concepts for lightweight, accurate antenna needs. New fabrication and assembly need to be developed. Maintaining relative position of a large number of dipoles and their sources presents a problem different from that of the reflectors and the solar array.

The general approach is to develop both reflector and array technology through the verification of the concept on shuttle flight(s).

A space experiment is needed as a qualification tool since these large antennas must be designed for zero-g environment. The gravity effect on such large lightweight antennas on earth create unacceptable structural deflection and loads, stressing the structure beyond its limits, and leading to collapse of the structure under its own weight.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Large Aperture Deployable Antenna Structures PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Achieve technology readiness by 1983 for 100 m antennas of 1 mm surface accuracy to be furled into a single package in shuttle and demonstrate operation with a shuttle flight experiment

4. CURRENT STATE OF ART: ATS-6 operational antenna, 10 m size 3 mm accuracy

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

There exists two types of microwave antennas: (1) the reflector(s) with a single RF (radio frequency) source (2) the flat array made of a large number of dipoles with phased RF sources.

The present reflector technology consists in stretching a reflective mesh on a light weight deployable frame, such as pivoting ribs, accurately positioned by mechanisms. Dimensional stability is a primary requirement that can be achieved by the use of composite materials.

New concepts for configuration, packaging and deployment will be investigated together with active shape control to reach the 1985-2000 size and accuracy requirements.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a.) Earth observations and communication satellites for the 1985-2000 period require large aperture space antennas of 100 meters in diameter with 1 mm surface accuracy to be operated in the cm wavelengths.

b.) The benefitting payloads are the objectives of themes 02 through 05 of OFS.

c.) The state of the art can produce 15 meter antennas with 1 mm surface accuracy by 1977. New methods to maintain the surface accuracy of 1 mm for 100 meter size must be developed, for example an active shape control.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT

NO.

1. **TECHNOLOGY REQUIREMENT(TITLE):** Large Aperture Deployable Antenna Structures

7. **TECHNOLOGY OPTIONS:**

Space experiment is needed because the one-g environment on earth creates unacceptable distortions due to structural weight.

Designing large space antennas with only ground demonstration is a possible option only for the smaller sizes, weight will become too large for the larger size.

8. **TECHNICAL PROBLEMS:**

The major problem is to maintain the high degree of accuracy of a light weight surface when size is increased, since the deviation from the desired surface increases proportionally with size.

9. **POTENTIAL ALTERNATIVES:**

None

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

On-going programs:

1.) OAST RTOP 506-17-15 "Advanced Concepts for Spacecraft Antenna Structures" (FY 76 last year funding)

2.) OA RTOP 645-25-02 "Large Antenna Shuttle Experiment"

EXPECTED UNPERTURBED LEVEL 4

11. **RELATED TECHNOLOGY REQUIREMENTS:**

- Composite Technology
- RF Feed Technology
- Actively Controlled Surface

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Large Aperture Deployable Antenna Structures

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. 15 m size																			
2. 100 m size																			
3. Flight demonstration																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ______
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structures

2. TITLE Large Aperture Antenna Structural Demonstration

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	4	7

An earth orbir ex,eriment for antenna components and full size, complete deployable large aperture antenna is required to demonstrate operation in zero-g environment and qualify the antenna.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1987
PAYLOAD DEVELOPMENT LEAD TIME 4 YEARS. TECHNOLOGY NEED DATE 1983

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Will extend size limit of large antennas operating at high radio frequencies up to 30 GHZ without in-space assembly.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS The major problem is to maintain a high degree of accuracy of a lightweight surface when the size is increased. The distortion from the desired surface increases with size.

REQUIRED SUPPORTING TECHNOLOGIES Deployment and packaging techniques; Composite materials technology; Feed technology; Actively controlled structures, sensor technology

7. REFERENCE DOCUMENTS/COMMENTS Forecast for Space Technology July 15, 1975 (OFS)

FT (TDR-1) 7/75

TITLE Large Aperture Antenna Structural Demonstration

NO.

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: 100 memter deployable antenna with 1mm surface accuracy.

TEST DESCRIPTION: ALT. (max/min) / km, INCL. deg, TIME hr

Antenna deployment in orbit, evaluation of surface accuracy in orbit, RF test in orbit, antenna furling.

BENEFIT OF SPACE TEST: Verify deployment and operational capability

EQUIPMENT: WEIGHT TBD kg, SIZE X X m, POWER TBD kW

POINTING TBD STABILITY DATA

ORIENTATION TBD CREW: NO. OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES: TBD

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE

9. GROUND TEST OPTION TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS: No ground test option

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: one-g environment gives unacceptable distortion, artificial zero-g on the gound is not practical.

TEST CONFIDENCE

10. SCHEDULE & COST

TASK	CY	78	79	80	81	82	83	CCST ($)
1. ANALYSIS		—	—					
2. DESIGN			—	—				
3. MFG & C/O					—			
4. TEST & EVAL						—	—	
TECH NEED DATE								
		GRAND TOTAL						

SPACE TEST OPTION (above)

GROUND TEST OPTION

						COST ($)
GRAND TOTAL						

11. VALUE OF SPACE TEST $ (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $

F1 (TDR-2) 7/75

LARGE, ERECTABLE SPACE STRUCTURES

I. Title:

Large Erectable Space Structures

II. Objectives:

To develop the technology for large erectable structures that can be delivered into space, unpacked, assembled and maintained to the require precision in orientation, accuracy of shape, thermal stability, and rigidity, and to demonstrate operation in earth orbit by a shuttle flight experiment.

III. Scope and Justification:

Each of the twelve themes in the OFS for the 1985-2000 period require large erectable space structures for space activities that include large microwave antenna (100 meters to one kilometer diameter), very large solar arrays (45 square kilometers), radiators, solar sails, telescopes and space platforms.

The technology requires the development of a totally integrated structural system of optimized basic structural elements which maximize commonality between configurations and which are used for assembly in space in modular form. Polymer and metal matrix composites, foams, and inflatables will be evaluated for the basic elements. The structural elements will be designed for the space environment to provide thermal distortion-free structures, dimensional stability, and maintenance of precise shape or element position. The structural design will be amenable to advanced structural analysis. Analysis in conjunction with ground tests will determine the accuracy limits of the configuration contour and distortions due to forces in space such as solar pressure, gravity gradient, aerodynamic forces, etc. It will then be determined if passive systems can be used to meet the accuracy requirements or whether a system will have to be incorporated that senses shape and position of elements and applies correction. Accuracy of shape and surface is critical for antennas and especially for microwave reflectors. The surface accuracy should be within one-tenth to one-sixteenth of the signal wave length.

IV. Approach:

The approach is to develop the technology needed for the numerous applications of large erectable structures using analytical and ground development tests. Space assembly techniques involving unique handling, joining, fastening, and aligning techniques will be developed. These techniques will be demonstrated on shuttle flights. Demonstration of large erectable structural systems will be on shuttle flights using modules of sufficient size with all systems operational. Since structural configurations will vary with application requirements, multiple shuttle flights will be required. Tests in a space environment are essential since these structures are designed for zero-g. The gravity effect on large lightweight structures on earth would cause large structural loads and deflections and perhaps cause failure.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): ____ PAGE 1 OF 3

Large Erectable Space Structures

2. TECHNOLOGY CATEGORY: Structures and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of erectable structures for space application to meet the needs of passive and active antenna. Advancement is needed to meet size, and accuracy requirements.

4. CURRENT STATE OF ART: Earth-bound structures, such as antennae, have not been designed for the space environment or the constraints of extreme accuracy dimensional stability or space erection considerations.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY A novel structural concept, which will provide great potential for new space capability in 1985-2000 time period, is large erectable space structures. As in the past, the structural requirements for the majority of applications are either larger antennae or larger relatively flat surfaces. Future applications require, in many cases, extreme dimensional stability and maintenance of precise shapes or element position. A complete new technology needs to be delivered into space, unpacked, assembled, and maintained with the required precision and orientation, shape, thermal stability, and rigidity. Some of these structures will be in the several kilometer size range, and in many cases their surfaces will have to be shape controlled to the centimeter or millimeter range.

The technology requires the development of optimized structural elements using a variety of materials and shapes that will allow assembly in space. Development of unique handling, joining, fastening and aligning techniques must be developed and considered in the total system concept.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Critical parameters are the large size, high configuration accuracy, and dynamic pointing control capability needed for advanced antennas, telescopes, and solar arrays.
b. Benefitting structural systems are all non-optical earth science and deep space antennas greater than approximately three meters in diameter, and large solar cell arrays on the order of one kilometer in size.
c. Allows full realisation of signal gathering potential of large antennas and telescopes, and improved structural efficiency of large solar cell arrays.
c. In orbit test will demonstrate technology readiness.

TO BE CARRIED TO LEVEL ____

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Large Erectable Space Structures

7. TECHNOLOGY OPTIONS:

The erectable antenna will be considered from a total systems concept and will include the dynamic interactions between structures, attitude control and shape control systems. Final shape, modular design, structural element design, material selection, fabrication, packaging and erection in space must be considered. Analyses of structural and dynamic characteristics must receive comprehensive investigation. Shape control and accuracy are critical parameters.

8. TECHNICAL PROBLEMS:

Large erectable antennae are a new technology which encompasses defining a concept or system of unprecedented size and dimensional accuracy. The shape and form of structural elements and materials must be developed. Design and development of the systems to maintain critical antenna parameters is required. This being a complex new technology, it is subject to research problems and protracted development.

9. POTENTIAL ALTERNATIVES:

None identified to date.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Conceptual studies are being conducted.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

1) Development of control systems to maintain surface accuracy and shape.
2) Develop building block structural elements of materials such as composites.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Erectable Structures PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	[illegible]	[illegible]	87	88	89	90	91		
TECHNOLOGY																			
1. Anal./Design																			
2. Fab.																			
3. Test																			
4. Doc.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ________
PAGE 1

1. REF. NO. ________ PREP DATE ________ REV DATE ________ LTR ____
CATEGORY Structures

2. TITLE Large Erectable Space Structure - System Development Test

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	3	7

Large space structures erected in space are required to serve as collectors and arrays for earth oriented and extraterrestrial scientific investigation. The large size and extreme accuracies require concept verification in a space environment. Full size structural elements and representative sections of the total system will provide data to continue the development of the total system.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1990
PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ________

TECHNICAL BENEFITS Development of large structures of required accuracy and controlled shape to permit accomplishment of a large number of scientific experiments.

POTENTIAL COST BENEFITS The large number of applications indicates a study requirement to determine cost benefits.

ESTIMATED COST SAVINGS $ TBD

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS This is a totally new structural system using elements and modular construction for assembly in space. Thermal and other space induced causes of shape or surface distortion must be passively or actively compensated to achieve the required geometric accuracies.

REQUIRED SUPPORTING TECHNOLOGIES a. Development of thermal-distortion-free structures. b. Development of basic elements-building blocks c. Sensor and surface shape control systems. d. Light weight structures - composites

7. REFERENCE DOCUMENTS/COMMENTS ________

FT (TDR-1) 7/75

TITLE ______ NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Modular section of a large structure

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr

The structure is to be transported by the shuttle and assembled in space.

BENEFIT OF SPACE TEST: To conduct demonstration and acquire design data for zero g and space enviroment.

EQUIPMENT: WEIGHT TBD kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____/____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TBD TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: Existing facilities are available to conduct development tests in 1g.

EXISTING: YES [X] NO ☐

GROUND TEST LIMITATIONS: Gravity effects are significant to overall system performance and therefore ground will not satisfy technology requirement. TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	80	81	82	83	84		SPACE COST ($)							GROUND COST ($)
1. ANALYSIS		→	→												
2. DESIGN		→	→	→											
3. MFG & C/O		→	→	→	→										
4. TEST & EVAL		→	→	→	→	→									
TE: ': NEED DATE															
GRAND TOTAL									GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

Accurate Shape Control

COST RISK $ ____

F T (TDR-2) 7/75

BASIC STRUCTURAL ELEMENTS

I. Title:

Basic Structural Elements

II. Objectives:

Develop basic structural elements for the fabrication and/or assembly in space of large structures.

III. Scope and Justification:

The ability to construct and maintain very large structures in earth orbit is imperative to serious consideration of meeting the requirements of space utilization as outlined in the Outlook for Space study.

The large structures required are unprecedented and require the full application of already developed expertise and the extention of that expertise to the necessary new dimensions. Current spacecraft are relatively small, launched in fully assembled configuration and consequently primarily designed by the launch environment. The large space structures will be fabricated and/or assembled in space and therefore, not subjected to such critical loading conditions. The weightless environment of space and the relatively benign and/or controlled operational loads afford the opportunity to successfully utilize such structures in space.

New and unique structural concepts have not been developed to meet the goals fo large structures. Extrapolation of current technology to these huge structures will result in launch-packaged volume and weights that are prohibitive. To minimize transportation requirements the concepts must be easily and efficiently packaged. Modularity will be an important consideration in the final choice of concept design of these structures. Modularity not only eases assembly in space, but it also permits easier repairability, thus increasing service life.

The structures should be designed to utilize identical structural elements. Furthermore, concepts should include the ability to fabricate in space from material stock that can be transported into space in high density bulk quantities. Due to the very low density of the lightweight structural members, man and/or man-operated machines can be used to fabricate, in place, much of the structure from prepared stock and/or other moderate density materials.

IV. Approach:

A matrix of structural materials and design concepts will be considered and evaluated including metals, composites, adhesives, and metal/composite combinations.

These materials will be used to develop standardized structural members - tubing, I-beams, channels, etc. They will also be used to develop standardized joints (rivets, adhesives, welding, etc.).

Parameters involved in the required parametric analyses include the loads to be carried (tension, compression, bending, shear, etc.), resonant frequency, stiffness, shape, and local surface distortion.

One further step will develop the utilization of the space environment - vacuum, solar heating - to fabricate the larger structural members, the ability to bond composites, bond sandwich panels, pressurize lightweight modular inflatable structures, etc.

The calibration, alignment, and actively controlled shape of structural members after in-space fabrication and/or assembly must be addressed. This calibration and alignment must be done to identify actual characteristics of the structure which will vary due to material property scatter and the man or man-operated assembly techniques.

The shuttle's capability will be utilized as a research laboratory of common facilities for an adequate demonstration of the methodology of transporting and assembling common structural elements. This development will evolve into the optimum methods of low-cost fabrication of these common structural elements in space.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF ___

Develop Basic Structural Elements (Fabricate and Assemble in Space)

2. TECHNOLOGY CATEGORY: Structures and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop basic, common structural elements to be utilized in the fabrication/assembly of structural elements for large structures.

4. CURRENT STATE OF ART: The ability to utilize large structures has been limited by the use of unmanned, volume and weight limited launch vehicles

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

The development of modular, basic structural elements is required to satisfy the requirements of large spacecraft and instrument hardware (antennae, reflectors, collectors, etc.)

The key elements which will direct this design approach are low-cost, commonality, repairability, and refurbishment.

The zero-g environment permits the utilization of weak structural elements (packaged to sustain the launch environment and fabricated and assembled in space) as well as structural non-supportive (flimsy) surfaces so that a required mass of materials is required, even in very extensive structures.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

In-space fabrication of the very large but relatively flimsy structures from more dense material which is matched in density to the shuttle cargo bay will benefit from either manned or man-operated attendance.

The utilization of the Shuttle as a research laboratory and of common facilities for the fabrication and assembly of the structural materials is highly advantageous.

When developmental structural elements are transported by the Shuttle and assembled in space, this initial technology requirement will be satisfied.

In the evolution of structures, the ability to fabricate the common structural elements in space from basic material must be demonstrated. When basic structural material is transported by the Shuttle and fabricated in space, this technology requirement will be satisfied.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): ______ PAGE 2 OF ___

Develop Basic Structural Elements (Fabricate and Assemble in Space)

7. TECHNOLOGY OPTIONS:

A matrix of structural materials and design concepts will be considered and evaluated including composites and/or metal tubing, sections (I-beams, channels, etc.), and joints (rivets, adhesives, welding, etc.).

Parameters involved in the required parametric analyses include:

- load determination - tension, compression, bending, shear, etc.
- resonant frequency and mode shapes
- susceptibility of the design concepts and material to uneven heating under solar radiation, the resulting distortions, and consequent instabilities
- accuracy of the structural elements such as shape (knowledge to within perhaps one (1) millimeter in some applications) and local disoortion (maintained within ten (10) microns in some specific applications).

Low structural weight fractions can be achieved by the utilization of composite materials, machined thin-wall metallics, sandwich trusses, then film surfaces, etc.

The utilization of the space environment - vacuum and solar heating - to fabricate structural elements (i.e. bond composites, bond sandwich panels, pressurize inflatable structures, etc.) that are larger than can be handled by the shuttle as a single load.

8. TECHNICAL PROBLEMS:

The basic structural elements building block requirement may impose cost penalties in the development (non-recurring) of the new structural elements, but also a necessary weight penalty when actually utilized in the space environment (joints, attachments, etc.) dictated by the man-operated assembly procedure.

This weight increase must be traded off against the ability to package basic structural elements within the shuttle in an optimized method to sustain the launch environment, and therefore be designed for zero-g stiffness criteria.

Another technical problem exists in the calibration and alinnment of the structural members after manufacture from basic structural elements in space. This calibration/alignment must be done to identify actual characteristics of the structure which will vary due to material property scatter, and the man or man-operated assembly techniques.

9. POTENTIAL ALTERNATIVES

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) EGRET spacecraft, F. J. Cepollina, (301) 982-5913.

(b) RTOP W74-70824 (970-63-10), Teleoperator Control and Manipulation, W. G. Thornton, MSFC, Huntsville, Ala., (Ph. 205-453-5530)

(c) Contributing contracts -

(1) In Flight Maintenance Study
Martin NAS 9-8144

(2) Application of EVA Guidelines and Design Criteria
Matrix NAS 9-12997

(3) Maintenance of Manned Spacecraft for Long Duration Missions
Boeing NAS 2-3705

(4) Space Shuttle Support Equipment Requirements Study EVA/IVA
Hamilton Standard NAS 9-12506

(5) Study of Space Shuttle EVA/IVA Support Requirements
LTV NAS 9-12507

(6) Role of RMS in EVA for Shuttle Mission Support
Essex NAS 9-13717

(7) Study to Evaluate Effects of EVA on Payload Systems
Rockwell NAS 2-8249

(8) Space Shuttle Orbiter Logistics Support Plan
Rockwell SD-T3-SH-0188A

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

New material developments, including composites and combinations of metallics and composites, as well as new adhesives will ease meeting the stated recurring lower-cost and reduced complexity of fabricating and assembling large structures from a basic contingent of common structural elements.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 4 OF ___

Develop Basic Structural Elements (Fabricate and Assemble in Space)

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design, Analysis																			
2. Fabricate																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE: Opportunities exist for this technology in 1982

TECHNOLOGY NEED DATE																TOTAL
NUMBER OF LAUNCHES																

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ________
PAGE 1

1. REF. NO. ________ PREP DATE ________ REV DATE ________ LTR ____
CATEGORY ________

2. TITLE Basic Structural Elements

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	4	7

The ability to utilize large structures has been limited by the use of unmanned, volume and weight limited launch vehicles. The development of modular, basic structural elements is required to satisfy the requirements of large spacecraft and instrument hardware (antennae, reflectors, collectors, platforms, etc.).

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1990
PAYLOAD DEVELOPMENT LEAD TIME 7 YEARS. TECHNOLOGY NEED DATE 1983

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ________
TECHNICAL BENEFITS To demonstrate the components needed to fabricate and assemble in space the required large structures.

POTENTIAL COST BENEFITS The recurring costs will decrease due to the modularity of the design as well as the ability to repair and refurbish the structures.

ESTIMATED COST SAVINGS $ ________

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS A 10-meter deployable antennae has been utilized in space (ATS-6). The ability to fabricate and assemble structures beyond the capability to be deployed must be demonstrated in space in a zero-g enviroment. The ability to maintain the structure's shape and accuracy must also be demonstrated.

REQUIRED SUPPORTING TECHNOLOGIES 1) Attitude control systems (flexible structures) 2.) Advancement of composites, metals and adhesives 3.) Advancement of man or man/operated fabrication and assembly hardware and techniques.

7. REFERENCE DOCUMENTS/COMMENTS ________

FT (TDR-1) 7/75

TITLE ______ NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Prototype Large Space Structural Element

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Place prototype large space structural elements in orbit by fabrication and/or assembly in space using basic structural subelements.

BENEFIT OF SPACE TEST: Reduce risk associated with the development of large space structures (antennae, reflectors, collectors, platforms, etc.).

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Basic Structural Elements

TEST DESCRIPTION/REQUIREMENTS: Demonstration of the fabrication and assembly techniques utilizing the basic elements - under one g.

SPECIAL GROUND FACILITIES: Facilities for simulating the space environment (air bearing surfaces, etc.)

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Questionable whether the space environment can be simulated - zero-g and the use of man or man-operated assembly/fabrication devices.

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR 2) 7/75

THERMAL - DISTORTION
FREE
STRUCTURES

I. Title:

Thermal-Distortion Free Structures

II. Objectives:

To develop and verify materials, designs, fabrication and thermal control techniques required to achieve structural assemblies which are dimensionally insensitive to changes in thermal environment.

III. Scope:

To apply optimum design techniques to achieve structural assemblies and elements which meet stringent constraints on displacements and distortions required by telescopes, antennas, and other payloads which are subjected to time-variant heat loads and distributions. To integrate the disciplines of materials, design configuration selection, application of coatings insulation, heat pipes, and other devices into structural assemblies and structural elements which minimize thermal deflections.

High-resolution optical telescopes antennae, and spectrographs require structures with dimensional stability under a range of orbital heating loads and distributions.

IV. Approach

In a parallel development program, develop;

1.) materials with low coefficients of thermal expansion
2.) materials with extremely low and extremely high thermal conductivity
3.) laminates/combinations of materials which achieve unidirectional thermal stability and others which achieve multi-directional or volumetric thermal stability
4.) designs of integrated structures/thermal control devices/insulation/coatings optimized for minimum thermal deformations
5.) as results from above development program become available, the materials, techhiques and devices will be experimentally verified and integrated into element and assembly tests in ground facilities, culminating in verification in space in structural sub-assemblies.
6.) fabrication techniques for 3, 4, and 5 above.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Thermal-Distortion-Free Structures PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop and apply to structural design a combination of advanced structural materials, optimum structural concepts, and thermal control techniques to achieve thermally distortion-free (con'td pg 4)

4. CURRENT STATE OF ART: Elements of the technology exist to varying degrees of development. Materials with low thermal expansion coefficients in all directions (continued on page 4) HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

A long range integrated technology program tying together disciplines of materials, structural design, structural fabrication, and thermal control to achieve structural elements which are nearly distortion free to changes in thermal conditions. The approach taken will consider varying degrees and forms of inert behavior required, such as relative angular distortion constraints about orthogonal axes, relative axial displacements along orthogonal axes, and volumetric constraints. A ground and space verification/demonstration program will be continued.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Large high frequency antennae, large telescopes, and power relay systems which require dimensional stability.

b. Would result in structural dimensional stability required by above future programs.

c. Structural elements and assemblies tested on ground and in space to verify thermal distortion limits.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______ PAGE 2 OF 4

Thermal-Distortion-Free Structures

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

Difficulty in finding materials or combinations of materials which have low coefficients of thermal expansion in all axes. Limitations of thermal control coatings, heat pipes, and insulation.

9. POTENTIAL ALTERNATIVES:

Limit size and performance of telescopes, antennae, etc.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

On-going research includes metal matrix composites structures, improved heat pipe capability, and structural/thermal analysis techniques, in separate technology efforts.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Thermal coatings, large erectable structures.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): Thermal-Distortion-Free Structures

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Thermal-Distortion-Free Structures

Continued from Page 1

3. structures. To experimentally verify approach by space environment exposure of structural elements.

4. needed to be developed. Techniques of designing laminates require development. Optimum methods of integrating heat pipes, coatings, and insulation into the structures have been demonstrated in laboratory breadboards to a limited extent.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ________
PAGE 1

1. REF. NO. ________ PREP DATE 08/08/75 REV DATE ________ LTR ____
CATEGORY ________

2. TITLE Thermal Distortion-Free Structure Demonstration

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3-5	5	7

Develop and verify improved materials, design approaches, fabrication methods and thermal control techniques which result in optimum structural assemblies from the standpoint of dimensional sensitivity to changes in thermal environments. Detailed advances required include low expansion of liminates (fiber directions, etc.) integration of heat pipes and insulation into structures, and improved heat pipe designs.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1979

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ________
TECHNICAL BENEFITS Permits accomplishments of missions requiring high degrees of dimensional stability for antennae, telescope mounts.

POTENTIAL COST BENEFITS ________

ESTIMATED COST SAVINGS $ ________

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Materials limitations, fabrication technique limitations.

REQUIRED SUPPORTING TECHNOLOGIES Materials and materials processing, structural design, heat pipes (thermal control)

7. REFERENCE DOCUMENTS/COMMENTS ________

FT (TDR-1) 7/75

TITLE Thermal Distortion-Free

NO.

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Structural sub-assembly consisting of joints and typical elements.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Zero-g permits unloaded joints for accurate thermal conduction.

EQUIPMENT: WEIGHT 2,000 kg, SIZE 1 X 2 X 10 m, POWER ____ kW

POINTING ____ STABILITY ____ DATA deflections, thermal

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Structural sub-assembly ar ᵈ elements

TEST DESCRIPTION/REQUIREMENTS: vacuum, thermal, gravity load removal system (distributed loads)

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☒ NO ☐

GROUND TEST LIMITATIONS: Inability to completely counteract effects of gravity

TEST CONFIDENCE fair

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR 2) 7/75

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

ADVANCED COMPOSITE STRUCTURES

I. Title:

Advanced Composite Structures

II. Objective:

To provide the technology required for future space transportation systems and payloads that will permit the utilization of composite structures for cost-effective weight reductions and which will satisfy service life and reliability requirements.

III. Scope and Justification:

Composite structures are potentially attractive for weight saving and performance improvement in many space systems. Consequently, they are expected to play a major role in the development of weight-critical space systems. The versatility offered by the variety of matrix and fiber materials and the possible range of properties permits unique advantages for each application. In this section, consideration is limited to the critical composites technology needed for STS [e.g. the Large Lift Vehicle (LLV) and the Space Tug] and a broad class of relatively small payloads which have lightly loaded; stiffness critical structures. Other applications of composites are covered under other structures topics, particularly Large Deployable Structures, Large Erectable Structures, Fabrication of Structural Elements, and Thermal-Distortion-Free Structures.

Current state-of-the-art is well-advanced for epoxy matrix materials (<300°F) for highly loaded structures. Structural applications of high-temperature composites have not been reliably achieved and only limited effort has been directed to thin, lightly loaded, stiffness-critical application.

IV. Approach:

Two classes of composite structures are emphasized. One is high-temperature composites for earth entry vehicles, and the other is very thin moderate temperature composites for upper stages and payloads.

For the high-temperature class, the CASTS program will provide a 600°F graphite/polymide technology demonstrated by laboratory tests of a critical shuttle component which would be representative of a typical LLV component. A follow on to the Composites for Advanced Space Transportation Systems program is proposed which would fabricate and flight qualify a component for flight evaluation on the shuttle. Another program is p oposed here to provide a high-temperature (>800°F) metal-Matrix technology which would also involve laboratory demonstration of a shuttle component followed by shuttle flight evaluation. In addition to the advantage of potential higher temperature capabilities, the metal matrix with greater thermal conductivity would provide increased heat sink capability which could permit greater saving in TPS weight. The state-of-the-art for metal-matrix composites for complex structural configurations is considered to lag that for polyimides so that the proposed metal-matrix program would probably follow by three to five years.

For thin, moderate temperature (<300°F) composites, the earliest potential application is for the Space Tug. Technology efforts are underway at MSFC and LRC involving analysis and limited laboratory experiments. Since technology for the Tug will be needed by 1978, it is suggested that a program involving some large-scale laboratory demonstration tests of thin-composite structures be initiated in the near future. It is recognized that potential degradation of the composite materials due to exposure to the space environment is an open question, but there appears to be no opportunity to resolve this question with long-term materials exposures prior to the shuttle operational era. Protective coatings will be necessary, especially for thermal control, and these should provide protection against some of the environmental hazards. These thin composite structures should also be attractive for a wide variety of payloads where stiffness with minimum weight is important to performance and cost. A continuation of current ground-based technology efforts resulting in laboratory demonstration of application to a typical critical payload structure should be adequate. Space flight experiments are not proposed.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): ____________ PAGE 1 OF ___

Advanced Composite Structures

2. TECHNOLOGY CATEGORY: STS Structures

3. OBJECTIVE/ADVANCEMENT REQUIRED: Composite structures for high temperature/high load and medium temperature/low load applications which will significantly reduce weight and cost of future space transportation systems and payload.

4. CURRENT STATE OF ART: Materials development, fabrication techniques, structural analysis and small component lab tests have been conducted with limited success at temperatures to 260°C (500°F) HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Advancements required in the following areas:

a. High-temperature composites and adhesives suitable for structures to 600°F with PI matrix and 800°F with light alloy metal-matrix materials. Current state-of-the-art is essentially limited to epoxy matrix materials (>300°F). Structural applications of PI and metal-matrix materials at higher temperatures have not been reliably achieved.

b. Very thin composites for moderate temperatures (>300° F) for lightly-loaded, stiffness-critical structures such as space tug and components of many payloads.

Current state-of-the-art is rapidly maturing for highly loaded, moderate temperature structures, but little has been done on development of very thin composites for lightly loaded space structure.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Advanced STS such as Space Tug and Large Lift Vehicles will demand lightweight structures for operational economic viability. For payloads to be transported beyond low earth orbit, weight is a primary factor for transportation cost.

b. All payload systems will potentially benefit from reduced transportation costs; geosynchronous, lunar, and planetary systems will reap the greatest benefits.

c. The level of technological maturity required in these composite applications is generally level 7 because demonstration in the appropriate space or entry environment maybe necessary to reduce the risk in design of operational systems to an acceptable level. The approach involves laboratory testing in simulated environments followed by testing in the space environment.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______ PAGE 2 OF __

Advanced Composite Structures

7. TECHNOLOGY OPTIONS:

a. High-temperature composites

Increased temperature capability for earth to orbit transportation system structures will permit direct savings in TPS weights. These savings coupled with those possible with the increased strength/density of composites over metal alloys lead to the potential of increased payload or decreased system size for a given payload.

b. Thin Composite Structures

Significant payload weight savings will be possible for a wide variety of systems which are lightly loaded in space operation.

8. TECHNICAL PROBLEMS:

There have been difficulties in obtaining consistent and reliable results in the necessary experimental hardwares leading to premature failures and significant increases in the cost of achieving the state-of-technology required.

9. POTENTIAL ALTERNATIVES:

The primary alternative is to continue the use of existing metallic structures; the weight penalties will be increasingly severe for the larger systems proposed and space transportation cost would be significantly increased.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

R & T Base activities in high-temperature composite material development and in lightly loaded composite structures. EXPECTED UNPERTURBED LEVEL 4

Systems Technology activities in CASTS program will result in laboratory tests of a 600°F composite structure component. EXPECTED UNPERTURBED LEVEL 5

Tug structures studies at MSFC related to lightly loaded composites. EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Other composite structures technology requirements are covered in Thermal-Distortion Free Structures, Deployable Structures, Erectable Structures, and Basic Structural Elements.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Composite Structures PAGE 3 OF 3

12. Technology Requirements Schedule

a. Assumptions:
1) Technology for Large Lift Vehicle (LLV) required by 1985.
2) Technology for Lightly-loaded composite structures needed by 1978 for Space Tug.

b. Technology Program Requirements:
1) High temperature composites
(a) Follow-on to CASTS program
Initiate in 1980: Fabrication of flight-qualified PI structural component (600°F capability) for operational shuttle for flight verification of technology by 1985.
(b) Metal Matrix Technology
Initiate in 1978: Design and fabrication of a metal-matrix component (>800°F capability) for laboratory testing to provide an option for LLV structure by 1985.
Initiate in 1984: Fabrication of flight-qualified metal-matrix component for operational shuttle for flight verification of technology by 1989.
2) Lightly-loaded components
Initiate in 1976: Design and fabrication of a large, very thin composite shell for laboratory tests to demonstrate feasibility for Tug structure by 1978. Subsequent activity to demonstrate feasibility for a variety of other applications by 1981.

FUTURE TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ____
PAGE 1

1. REF. NO. ____ PREP DATE ____ REV DATE ____ LTR ____
CATEGORY Structures

2. TITLE High-temperature Polyimide composites shuttle flight experiment.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	5	7

Polyimide composite structures for 315 degree C (600 degree F) long life in reusable large life vehicles.

4. SCHEDULE REQUIREMENTS FIRST FLIGHT DATE 1990 (assumed)
PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS N/A

TECHNICAL BENEFITS Weight savings of 30% or more in LLV structures permitting equivalent reductions in lift-off, entry, and landing weights provided that the necessary state-of-the art level is available prior to critical design decisions for the LLV.

POTENTIAL COST BENEFITS Significant cost savings in development and oeprational costs for LLV resulting from reduced weight and size.

ESTIMATED COST SAVINGS $ ____

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Achievement of the temperature and service life objectives requires substantial improvements in polyimide materials properties, processing and fabrication, and successful lab tests of a complex structural component prior to design and fabrication of a flight-test component.

REQUIRED SUPPORTING TECHNOLOGIES Polyimide matrix and adhesive materials development. Completion of current CASTS program by lab tests of the shuttle component.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE High-Temperature Polyimide Composite Shuttle Flight Experiment NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Major shuttle structural component such as

TEST DESCRIPTION: ALT. (max/min) N/A / ______ km, INCL. ______ deg, TIME N/A hr

Substitution of composite component for metallic shuttle component for evaluation during routine shuttle flights.

BENEFIT OF SPACE TEST: Verification of adequacy of polyimide technology by exposure of full-scale component to actual mission environments.

EQUIPMENT: WEIGHT TBD kg, SIZE TBD X ______ X ______ m, POWER N/A kW

POINTING N/A STABILITY N/A DATA TBD

ORIENTATION N/A CREW: NO. N/A OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: Radiant heating structural test and high-temperature wind tunnels (8 ft. HTST and TPSTF) for lab tests prior to flight testing.

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: Same

TEST DESCRIPTION/REQUIREMENTS: Simulated environmental tests of full-scale composite component for Shuttle.

SPECIAL GROUND FACILITIES: Large high temperature hypersonic wind tunnel capable of imposing shuttle entry heating alternately with launch dynamic and acoustic loadings.

EXISTING: YES [ ] NO [ ]

GROUND TEST LIMITATIONS: The req ired ground facility would be prohibitively expensive; probably more than $100 M. If the facility were available, space and ground test costs would be equal.

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	SPACE TEST OPTION CY 80	81	82	83	84	85	COST ($)	GROUND TEST OPTION CY 80	81	82	83	84	85	COST ($)
1. ANALYSIS	✓							✓						
2. DESIGN	✓							✓						
3. MFG & C/O		✓	✓						✓	✓				
4. TEST & EVAL			✓	✓	✓						✓	✓	✓	
TECH NEED DATE						✓							✓	
GRAND TOTAL														

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

I I (1DR 2) / 75

STS

FUTURE ~~PAYLOAD~~ TECHNOLOGY NO. ______

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structures

2. TITLE High-Temperature Metal-Matrix Composites Shuttle Flight Experiment

3. TECHNOLOGY ADVANCEMENT REQUIRED
Metal-matrix composite structures for 425 Degree C (800 Degree F) for long life in reusable large lift vehicles.

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	4	7

4. SCHEDULE REQUIREMENTS FIRST ~~PAYLOAD~~ LLV FLIGHT DATE 1990 (Assumed)
PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS N/A
TECHNICAL BENEFITS Weight savings of 30% or more in LLV structures plus substantial weight savings in TPS (potential for eliminating TPS over large areas of the upper surface). Equivalent reductions will be possible in liftoff, entry, and landing weights provided that the necessary SOA level is available prior to critical design decisions for the LLV.
POTENTIAL COST BENEFITS Significant cost savings in development and operational costs for LLV resulting from reduced weight and size.
ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Achievement of the temperature and service life objectives requires substantial improvements in metal matrix properties, processing and fabrication, and successful lab tests of a complex structural component prior to design and fabrication of a flight-test component.
REQUIRED SUPPORTING TECHNOLOGIES Metal-matrix materials and joining methods development.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7/75

TITLE High-Temperature Metal-Matrix Composites Shuttle Flight Experiment

NO.

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Major Shuttle structural component such as an eleven.

TEST DESCRIPTION: ALT. (max/min) N/A / km, INCL. deg, TIME N/A hr

Substitution of metal-matrix composite component for metallic shuttle component for evaluation during routine shuttle flights.

BENEFIT OF SPACE TEST: Verification of adequacy of metal-matrix technology by exposure of full-scale component to actual mission environments.

EQUIPMENT: WEIGHT TBD kg, SIZE TBD X X m, POWER N/A kW

POINTING N/A STABILITY N/A DATA TBD

ORIENTATION N/A CREW: NO. N/A OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES: Radiant heating structural tests and high-temperature wind tunnels (8-ft. HTST and TPSTF) for lab tests prior to flight testing.

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE

9. GROUND TEST OPTION TEST ARTICLE: Same

TEST DESCRIPTION/REQUIREMENTS: Simulated environmental tests of full-scale component for Shuttle.

SPECIAL GROUND FACILITIES: Large high-temperature hypersonics wind-tunnel capable of imposing shuttle entry heating alternately with launch dynamic and acoustic loadings.

EXISTING: YES [ ] NO [X]

GROUND TEST LIMITATIONS: The required ground test facility would be prohibitively expensive: probably more than $100 M. If the facility were available, space and ground tests would be equal.

TEST CONFIDENCE

10. SCHEDULE & COST

TASK	SPACE TEST OPTION							GROUND TEST OPTION						
CY	78	80	82	84	86	88	COST ($)	78	80	82	84	86	88	COST ($)
1. ANALYSIS	✓							✓						
2. DESIGN	✓	✓						✓	✓					
3. MFG & C/O		✓	✓						✓	✓				
4. TEST & EVAL				Lab→	←→	Flight					✓	✓	✓	
TECH NEED DATE					✓	✓						✓	✓	
GRAND TOTAL														

11. VALUE OF SPACE TEST $ (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $

LONG

SLENDER

SPACE

STRUCTURES

I. Title:

Long Slender Space Structures (LSSS)

II. Objective:

To develop and test long slender structures designed specifically to position and permanently hold at large distance modular components such as antennas, optical components, detectors and measuring devices.

III. Scope:

Many porposed missions in the 1973 Mission Model and OFS consist of discrete components large distances apart which must maintain a constant geometric configuration. Gravity gradients, solar wind, thermal distortion, pointing maneuvers, docking operations and many other external disturbances will cause these components to move relative to one another. It is desirable to restrict the changes in these configurations by a simple, low-cost, efficient structure requiring a minimum of servicing. In many instances the perturbing forces will be small and position-accuracy will not be extremely critical. For these applications, a light-weight, cable-stiffened structural assembly could be used to hold the components and maintain the geometry of the system. For other applications, the geometry must be maintained to such a close tolerance that an active control system may be necessary to meet the requirements. It is not clear what the upper limits of size are for simple passive structures before it becomes necessary to use active control systems to maintain positioning accuracy. Much of this work will be done with analysis and ground test, but verification can only come with an experiment in space.

The advancement would make possible, at a reasonable cost, the construction of synthetic aperture radar antennas, large deep-space radio telescopes, rhombic antennas and earth resource surveys.

IV. Approach:

Development of materials and design concepts for simple structural elements will be initiated. A thorough analysis on the limits of size and positioning accuracy will be made using known information on the forces which can perturb the geometry. Optimal designs will be considered from the beginning of the study in order to achieve a minimum weight design. After determining the size/positioning accuracy envelope, consideration will be given to actively controlling the deformation of the structure. Attention will be given to accurate representation of the flexibility of the structure and an effort will be made to optimize the integrated structure/control system. The complete active control spectrum will be examined ranging from passive structural stiffness with no control to systems with no structural connection and some other station-keeping scheme such as thrusters, magnetic or electric fields.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ____

1. TECHNOLOGY REQUIREMENT (TITLE): ____ PAGE 1 OF 2

Long Slender Space Structures (LSSS)

2. TECHNOLOGY CATEGORY: Structures

3. OBJECTIVE/ADVANCEMENT REQUIRED: Long slender structural assemblies to position and permanently hold small modular components in near-earth and geo sync orbit

4. CURRENT STATE OF ART: Deployable booms such as the Astromast and the DeHavilland boom

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Development of new designs of long slender structural assemblies using combinations of cables, beams and similar simple structural components, subject primarily to tension and compression, to be used to position small antennas, optical components, detectors, measuring devices, etc., in space during assembly and operation . . . consider the integration of active control systems to enhance the performance of the structure.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Many planned missions, both in the 1973 Mission Model and Outlook for Space, require positioning of discrete components wide distances apart. Forces are present, such as attitude control, solar winds and gravity gradients, which cause serious changes in geometric configurations. Some of the components require accurate positioning relative to one another while for others positions is not extremely critical. A light weight, low cost, simple structure to preserve the geometry is desirable.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ______________ PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

Studies should be made to determine the upper limits on size and positioning accuracy. For certain tolerance requirements, active structural control might be necessary to meet positioning accuracy. A thorough study will be made to determine the range of parameters for which passive structural elements will suffice and for what range active controls will be necessary.

8. TECHNICAL PROBLEMS:

Thermal distortion, static and dynamic structural stability, local carrying capacity, stiffness, active control, assembly in space, connectors (joints), degradation of materials by radiation or fatigue.

9. POTENTIAL ALTERNATIVES:

Station keeping of discrete components by thruster, magnetic or electrical fields with no interconnection of elements.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

No information.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Composites, active structural control considering elastic deformation, low CTE materials, fatigue, effect of radiation on material properties.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. LSSS-1
PAGE 1

1. REF. NO. ______ PREP DATE 08/14/75 REV DATE ______ LTR ______
CATEGORY ______

2. TITLE Long Slender Space Structures (LSSS)

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	3	7

Develop and test long slender space structures designed specifically to position and hold at large distances modular components such as synthetic aperture antennae, in a fixed geometric configuration; determination of the size/geometric accuracy envelope is an important consideration.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1986
PAYLOAD DEVELOPMENT LEAD TIME 4 YEARS. TECHNOLOGY NEED DATE 1982

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Advancement would make possible synthetic aperture radar, large deep-space radio telescopes, rhombic antennae, long booms to hold sensing and measuring devices away from other structures to avoid contamination and/or interference.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Integration of active controls into structural systems, prediction/solution of structural stability problems, thermal distortion, optimizing strength/stiffness per unit weight/length.

REQUIRED SUPPORTING TECHNOLOGIES Materials, controls

7. REFERENCE DOCUMENTS/COMMENTS 1975 NASA OAST Summer Workshop, Outlook for Space.

FT (TDR-1) 7/75

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Long Slender Space Structure

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Assemble and test a long slender space structure to verity upper limits on positioning accuracy.

BENEFIT OF SPACE TEST: Provide adequate demonstration of the stability and effectiveness of structure under solar heating, solar winds, gravity gradient, etc.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Long Slender Space Structure

TEST DESCRIPTION/REQUIREMENTS: No ground test option

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Lack of zero-g for length of structures to be considered

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 76—79	80	81	82		COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS														
2. DESIGN														
3. MFG & C/O														
4. TEST & EVAL														
TECH NEED DATE														
		GRAND TOTAL						GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

F1 (1DR 2) 7/75

RELIABILITY

&

LIFE

PREDICTION

I. Title:

Reliability and Life Prediction

II. Objective:

To develop an overall design life philosophy for space structures. Within this objective there are four main themes: 1.) Extend analytical procedures for fatigue and fracture phenomena, 2.) Provide empirical data from which to verify analysis, 3.) Develop structural system in-space checkout instrumentation; i.e., laser holography 4.) Develop onboard monitoring systems to provide structural history, warning of imminent failure and/or alert for replacement of failed elements.

III. Scope and Justification:

Due to the high cost and weight sensitivities of spacecraft, accurate and reliable structural life predictions are mandatory. For example, it will be both technically and economically a disaster if the first Mars sample return mission fails during the return leg because of a flaw in the thrust structure. All space systems are similarly affected. If we can accurately predict the life of the structure, we can design it to have no more than the desired life. Thus, the system will be lighter and lower in cost. However, the current state of the art in structural life prediction is limited to empirical analyses of flawed structures on the basis of destructive test data from simply loaded specimens. Analytical elastic solutions are available for a small number of relatively simple loading conditions.

IV. Approach:

During the last decade, a great deal of effort has been expended on fracture mechanics and structural life analyses. To date, however, there exist semireliable relationships between stress and cycle life for only the most simple structures. If the structure or the load condition is in any way complex, any attempt to predict life may be in error by one or more orders of magnitude. Thus, the general approach to be pursued by this technology area will be to evaluate space structures from both a fail-safe and safe-life design and at the same time to develop the capability to locate manufacturing defects which could cause premature structural failure. Then, having the capability to reliably locate defects, the necessary techniques to evaluate the effect of the defect on subsequent structural life will be developed. Where applicable, instrumentation necessary for continuous life monitoring of critical structural elements will be developed. Primary emphasis will be placed on thin, tough metallic and composite structures because of their overall importance to space structures and because they are generally the most difficult problem. The understand- of flaw behavior and slow crack growth in these systems will provide meaningful methods of proof testing and life prediction.

Because large space tankage generally will be one of the most critical flight safety items, fracture studies in lightweight metal or composite tanks will be emphasized. Basic technology needs will be for development of elastic-plastic failure criteria to predict conditions under which leakage and fracture failures will occur, standardization of fracture/crack propogation test methods for tough thin gage materials, and enlargement of data banks. Criteria for rejection or acceptance of flight hardward specified for long-time operation will be re-examined carefully. Because of their potential efficiency, serious efforts to develop reliable composite tanks will continue. Improved fabrication techniques for forming and joining thin liners to penetration fittings will be developed, as well as refined design concepts to minimize local strain concentrations and use of higher modulus fibers to minimize liner cycling effects. Load-bearing tankage concepts will also be explored.

To enhance vehicle reliability, significant advances in the state-of-the-art of nondestructive evaluation will be made. Improvements in flaw detection are expected to provide a major improvement in the reliability of high strength materials. Flaws controlling fracture are frequently in the size range of one mm or less, and present technology has not been adequate to detect them reliably. Techniques being evolved, employing interference analysis of shortwave-length energy waves, such as frequency acoustics and eventually x-rays, coupled with extensive computer analysis of the data generated, should permit reliable nondestructive testing (NDT) of structural materials. Such improvements are predicated on a steady, long-term commitment to NDT development. Field measurements techniques rather than readouts of data-at-a-point will be employed to check large components. Advanced inspection systems will be developed by exploiting candidate test techniques such as acoustic and pulsed holography, infrared thermography with image enhancement, acoustic emissions, microwave scanning, fiber optics, combined with low light level TV, and neutron radiography. Dynamic test techniques using more automated data reduction techinques, programmed multishaker controls, and variable random/sinc/impulse forcing functions will provide considerably more information per unit of test time for large vehicles. General technology thrust in the structural test area will obtain more depth of data on strength, stiffness and dynamic behavior at both micro and macro levels.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Reliability and Life Prediction. Non-destructive evaluation of structural life &/or reuse capability PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop space-borne inspection techniques to monitor fabrication of and detect flaws in space structures and to develop onboard monitoring of general spacecraft tankage and structural systems.

4. CURRENT STATE OF ART: Current state-of-the-art is limited to empirical analysis of flawed structures on the basis of destructive test history on simply loaded specimens. Analytical elastic solutions are available for a small number of loading conditions

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

General formulas relating cyclic life capabilities of speciments subjected to a basically elastic stress field are relatively well advanced. Proof test philosophies exist which estimate initial flaw size and cyclic crack growth rates. However, even current state-of-the-art cannot predict life for tough, thin materials or for composite materials. Thus, current technology must be advanced to provide an analysis capability for elastic-plastic stresses in a complex stress field and for thin gauge metals and composites. In addition, flaw detection equipment and procedures must be advanced for semi-automated checkout of structures in space. Fail-saft versus safe-life design theories would also be developed.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Advanced technology is required for instrumentation and techniques. Once a structural life can be predicted, structures can be designed in a more weight (and cost) effective manner.

(b) All spacecraft

(c) Improved performance, less risk, heavier payload, less weight

(d) Technology should be advanced through the space experiment level (07). To achieve this, analysis techniques, special methods of processing of large structures, and additional testing of metallics and composites in a laboratory environment would be investigated.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Reliability and Life Prediction. Nondestructuve evaluation of structural life &/or reuse capabilities. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

A typical example of the value of life prediction is the effect it can have on pressure vessels. Typical man rated pressure vessel safety factors run in the range of 1 ½ to 2 for a relatively low (1000) cyclic life tank. If life could be predicted through a combination of facture mechanics and crack growth data, potential safety factors of 1.1 to 1 could be met. This would result in weight savings of 37 tc 45%. Achievement of these goals will require development of non-destructive test theories, crack growth rate analysis and data, specimen standardization, failure theories and complex load analysis techniques along with flaw locating instrumentation and apparatus and onboard, real time structural monitoring devices.

8. TECHNICAL PROBLEMS:

The technical problems have been well documented, but specifically include: complexity of elastic-plactic stress field, difficulty of finding small, tightly closed cracks, confidence of finding all critical size flaws, transfer of technology from lab to space, and the physical size of the structures being proposed for space antennae and solar collectors.

9. POTENTIAL ALTERNATIVES:

Increased weights, risk and costs. Extensive qualification programs and minimum in-space fabrication are also potential tradeoffs.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP's

505-01-21, 505-17-32, 506-17-23, 505-02-31

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Holography, laser holography, ultrasonics, radiography, composites, materials.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

PAGE 3 OF 3

1. TECHNOLOGY REQUIREMENT (TITLE): Reliability and Life Prediction. Non-destructive evaluation of structural life and/or reuse capabilities

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14 REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT
7. MODEL TESTED IN SPACE ENVIRONMENT
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

FUTURE PAYLOAD TECHNOLOGY NO. ____

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ____ PREP DATE ____ REV DATE ____ LTR ____

CATEGORY Structures and Dynamics

2. TITLE Space Applications of Non-Destructive-Evaluation (SANDE)

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	5	7

For large structures which will require assembly in space, it will be necessary to perform the inspection and structural verification operations in space. The size of the structures involved will require some type of automated or semi-automated procedure. Thus, the capability of current NDE equipment and processes must be both improved and subjected to an in-space demonstration.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1990

PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ____

TECHNICAL BENEFITS This technology can provide benefits of reduced risk, decreased test time on the ground, automated in space check-out, and a wider range of space based fabrication procedures.

POTENTIAL COST BENEFITS Broader range of fabrication procedures may be used since it will not be necessary to apply inspection controls. Testing costs both on the ground and inspace may be greatly reduced.

ESTIMATED COST SAVINGS $ ____

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Large size of items to be inspected and requirement for remote non-contacting sensors are expected to be main problem areas. Evaluation of data will also be a difficult problem.

REQUIRED SUPPORTING TECHNOLOGIES Sensor design, holography, lasers, radiography

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE ______ NO. ______
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Erected space structure will serve as test bed for new and/or improved NDE procedures and apparatus.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Place samples with known defects in orbit and also fabricate representative sections of a space structure to use as object of NDE process.

BENEFIT OF SPACE TEST: Demonstrate that structure fabricated in the space environment can be adequately inspected.

EQUIPMENT: WEIGHT TBD kg, SIZE ____ X ____ X ____ m, POWER 1 kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. TBD OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: Ground checkout and performance will be performed but final system demonstration must be performed in space.

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: This NDE system will ultimately be used for checkout of systems assembled in space. Therefore, system performance must be verified in space.

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION							GROUND TEST OPTION						
								COST ($)							COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F T (T DR-2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ______

PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ____

CATEGORY ______

2. TITLE In Space Development of Inspection Process (ISDIP)

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	3	7

Conventional inspection equipment and processes are often limited by background vibration, noise, and/or other interference. The potential of the space environment to provide an interference free background would thus be developed to provide for advance non-destructive inspection capabilities. Special emphasis would be placed on increased scanning speed as required for LASS and on improved reliability and sensitivity as required for both earth and space based critical structure (pressure vessels, highly loaded thrust structures, etc.)

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1985

PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1982

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Improved scanning speed, reliability, and sensitivity of nondestructive inspection processes will provide reduced risk and greater mission reliability.

POTENTIAL COST BENEFITS Advanced inspection concepts will lead to reduced testing requirements and costs. In addition, manufacturing processes will not be inspection limited. Vehicle design can incorporate improved inspection by use of low risk factors and thus achieve lighter weights and lower costs.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS The major technical problem will be in designing of new inspection apparatus and in completely isolating the experiment from background interference.

REQUIRED SUPPORTING TECHNOLOGIES Sensor designs, holography, lasers, radiography

7. REFERENCE DOCUMENTS/COMMENTS ______

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TITLE ____________________ NO. ________
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Improved and/or redisigned inspection apparatus of various types.

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr
Use man in space lab to operate inspection equipment on prepared test samples

BENEFIT OF SPACE TEST: Space environment is expected to enhance inspection capability.

EQUIPMENT: WEIGHT TBD kg, SIZE ____ X ____ X ____ m, POWER ____ kW
POINTING ____ STABILITY ____ DATA ____
ORIENTATION ____ CREW: NO. TBD OPERATIONS/DURATION ____/____
SPECIAL GROUND FACILITIES: ____
EXISTING: YES ☐ NO ☐
TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Ground checkout and performance will be performed, but final system demonstration must be performed with man working in space.

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: Cannot provide total space background on earth, and this system will ultimately be used for inspection of structures which will be fabricated and therefore must be tested in space. EXISTING: YES ☐ NO ☐
GROUND TEST LIMITATIONS: ____
TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

F1 (TDR 2) 7/75

INTEGRATED SYSTEM CONCEPTS

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I. Title:

Integrated System Concepts

II. Objective:

To develop concepts for large space systems in which component elements of the structure and system perform multi-disciplinary functions of structures, thermal control, and electrical conduction.

III. Scope and Justification:

Present system design philosophies are based on a modular approach. This modular approach (while providing the ability to repair or replace small components) is costly from weight and volume considerations. These considerations are important to all space payloads but for large structural systems and high-energy missions they are critical.

Much weight and volume is expected to be saved if an integrated system were developed to perform multiple functions (e.g. structural, thermal and electrical functions).

IV. Approach:

Materials and structural configurations will be evaluated as to their ability to perform multi-system functions simultaneously (e.g. load carrying, thermal control, and electrical). Control systems capable of stiffening the structure, controlling the surface shape, and attitude of the vehicle will be integrated.

Integral system analyses will be utilized that will permit the prediction of coupled structural flexibility, controls, and thermal responses. This analyses will have the capability of modelling all important subsystems and evaluating their coupled response. The analyses will then be used to obtain optimum designs of an integrated system.

This resulting system will then be compared to systems designed by the modular approach. Cost benefits studies will then be made to determine the feasibility of such system designs. If proven effective appropriate flight payloads will be flown.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. A - 1

1. TECHNOLOGY REQUIREMENT (TITLE): Integrated System Concepts PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Structure and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop concepts for large space system in which component elements of the structure and system perform multidisciplinary functions of structures, thermal control, and electrical conduction.

4. CURRENT STATE OF ART: All systems are designed to be functionally independent and are assembled into the spacecraft in a modular fashion.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Development of new structural configurations in which the functicns of structural stiffness, thermal control and electrical conductions are integrated.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The current state-of-the-art is costly from both weight and volume considerations. These considerations are critical to large space structures. Much weight and volume could be saved if a single system could perform the structural, thermal and electrical functions simultaneously.

TO BE CARRIED TO LEVEL 5

LOADS & RESPONSE DETERMINATION AND CONTROL

I. Title: Loads and Response Determination and Control

II. Objective:

To improve the prediction of dynamic loads on space and launch structures and to develop techniques for minimizing these loads as a significant cost driver in spacecraft and launch vehicle design.

III. Scope and Justification:

Considerable effort is currently expended in the design and development of space structures which will withstand the dynamic launch loads. Uncertainty as to what these loads will be for a particular payload/launch-vehicle combination, how to treat them analytically, and how to overcome their effects generally results in an extensive design iteration and test program. Current efforts are directed at improving the efficiency of this process and attenuating loads for shuttle payloads. However, for future applications, further development is needed which will improve the cost-effectiveness of these procedures. Furthermore, as very large erectable and deployable structures are developed, new response problems occurs. First, in order to launch these structures, very large launch vehicles will be needed which will create a new launch environment. Second, erection and operation of large 100m-10Km solar arrays, antennas, and space platforms will require prediction of a new set of dynamic loads. Examples are erection loads, solar wind, high frequency components of control forces, and dynamic effects of gravity gradients during attitude control manuevers.

IV. Approach:

Measurement of loads on a representative sample of payloads during early shuttle flights is required. Anlytical models for predicting these responses and test techniques for reproducing them will be updated with flight data. For large post-shuttle launch vehicles, automatic load alleviation techniques will be studied for alleviating loads in the payload bay (e.g. evacuated payload bays to reduce acoustic loads). For large structures operating in space, the dynamic loading effects of solar wind, changing gravity gradients during attitude changes, control forces, and erection loads will be evaluated on analytical models.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Loads and Response Determination and Control PAGE 1 OF __

2. TECHNOLOGY CATEGORY: Structures and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: To improve the prediction of dynamic loads on space structures and to develop techniques for minimizing these loads as a significant cost driver in spacecraft and launch vehicle design.

4. CURRENT STATE OF ART: Present capability to predict loads and control responses during launch results in design conservatism and extensive testing to assure reliability. H'S BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOL

Improve definition of dynamic loads and the resulting response of spacecraft during shuttle launch and develop more accurate analytical prediction methods. Study active load alleviation systems for advanced large launch vehicles. Develop understanding of dynamic loads such as control loads and solar wind on large space structures in orbital operation.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Critical parameters are the high cost of structural design iteration and test programs required for payloads to survive the launch environment, the large launch vehicle structures needed to make launch of 100m - 10Km space structures feasible, and the unknown loads and loading effects on large space structures.

b. Benefitting are almost all post-1985 payloads, large advanced launch vehicles, and large solar arrays, antennas, space platforms, and solar sails.

c. Improved capability for prediction and control of launch loads will reduce design uncertainty thus resulting in lower payload costs.

d. Mature level of technology would be the effective minimization of dynamic launch loads as a serious consideration in payload design and development; the demonstration of an effective dynamic load alleviation system on a space shuttle orbiter; and the complete definition of space operation dynamic loads and their effects on large area space structures.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT | NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ____________

Loads and Response Determination and Control

7. TECHNOLOGY OPTIONS:

Reduction of dynamic inputs during launch through improved flight controls, aerodynamic noise reduction, and quiet engines. The development of payloads which are not affected by helium would allow reductions of acoustic environments through the use of helium filled payload bays.

8. TECHNICAL PROBLEMS:

Limited analytical prediction capability for higher modes and acoustic responses; size and computer time requirements of analytical models

9. POTENTIAL ALTERNATIVES:

No potential alternatives.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Primary application effort is under RTOP 506017-31 "Payload Dynamics".

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Computer sciences, mathematical modeling, sensor technology, and flight controls technology are needed as inputs in achieving ultimate goals.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. ______
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structures and Dynamics

2. TITLE Shuttle Bay Dynamic Environment Measurement

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Definition of loads on shuttle payloads. Measurements of the dynamic environment including attachment forces are required for a representative sample of payload weights, volumes, densities, dynamic response characteristics and locations of attachment. Measurements are required to be comprehensive enough to evaluate payload/orbiter coupled dynamics and to allow separation of acoustically driven responses from structurally driven ones.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1984
PAYLOAD DEVELOPMENT LEAD TIME 4 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Improved loads prediction for future shuttle payloads.

POTENTIAL COST BENEFITS Reduced cost of payload design and development because of increased confidence in loads definition.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Integration and generation of required backup dynamic ground tests and analysis.

REQUIRED SUPPORTING TECHNOLOGIES Flight instrumentation, sensor design, dynamic modeling, dynamic and acoustic testing.

7. REFERENCE DOCUMENTS/COMMENTS This represents an extended program of the type proposed for LDEF by the Shuttle Bay Environments Measurement Panel at LaRC.

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TITLE Shuttle Bay Dynamic Environment Measurement NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Shuttle orbiter payloads during development flights.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Measure noise field in shuttle payload bay, payload vibrations, and payload attachment point forces.

BENEFIT OF SPACE TEST: Improved loads prediction for future shuttle payloads.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Ground test cannot properly simulate launch loads.

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FI (TDR 2) 7 75

FUTURE PAYLOAD TECHNOLOGY NO. ______

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______

CATEGORY Structures and Dynamics

2. TITLE Shuttle Orbiter Load Alleviation Experiment

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	4	7

Large Lift Vehicles (LLV) are required for a more cost-effective launch of large solar arrays, antennas, and space platforms. Active load alleviation for reduction of stress levels is required to allow lightweight LLV structures.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1990

PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Reduced loads on launch vehicle structures

POTENTIAL COST BENEFITS Reduced launch cost through higher payload/launch vehicle weight ratios.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Time varying structural dynamics during launch

REQUIRED SUPPORTING TECHNOLOGIES Aerodynamic controls, control and load alleviation technology.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE Space Shuttle Load Alleviation Experiment

NO.

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Active load alleviation system to be used in parallel with shuttle orbiter control system.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Demonstrate active load alleviation system feasibility and compare stresses on vehicle with and without control.

BENEFIT OF SPACE TEST: Includes longitudinal thrust and time-varying structural dynamics not available in aircraft flight tests.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR 2) 7/75

ACTIVELY CONTROLLED/STIFFENED STRUCTURES

I. Title:

Actively Controlled/Stiffened Structures

II. Objective:

To extend structural size limits and/or increase system stiffness required to maintain high configuration accuracy through control-augmented stiffness.

III. Scope and Justification:

This technology is directed at future requirements in both earth and space science for antennas, telescopes, and solar arrays which are orders of magnitude larger in size than current state-of-the-art structures. In view of the difficulty of a major advance in structural element design and/or materials, the construction of 5m. or larger optical telescopes or 100-meter to 10-kilometer in-space structures with the ability to be continuously pointed and/or maintain configuration accuracies on the order of 10^{-5} diameters will not be possible with passive structures. The use of active structures is considered to be a promising technique for maintaining configuration accuracies of structures.

IV. Approach:

As a first step, analytical models will be developed to study the dynamics of large, highly-flexible space structures under operational loads including altitude control. Active shaping and stiffening control forces will then be included and the structural dynamics/controls interaction effects will be studied. The nature, placement and number of controls needed for a variety of structural loads and configuration accuracy requirements will be evaluated. Trade-offs between local structural stiffness, mass, damping, and number and mass of controls will be evaluated.

Laboratory models will then be used to evaluate analytical models. However, because of the inability to simulate the space environment in the laboratory, in-orbit tests of one or more relatively-small (10-30m), highly flexible models are required to evaluate design techniques and analyses and to demonstrate technology readiness.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. ______

1. TECHNOLOGY REQUIREMENT (TITLE): Actively Controlled/Stiffened Structures

2. TECHNOLOGY CATEGORY: Structures and Dynamics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduce structural stiffness requirements for large space structures through active control of geometric configuration and dynamic response.

4. CURRENT STATE OF ART: Configuration control of small flexible mirrors attached to base structures has been demonstrated in the laboratory.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Extend the state of the art of actively controlling structural stiffness to a practical technique for application to ultra-large and/or highly accurate space structures. Forceseeable accuracy of passive structures preclude space structures which are in the 100m-10Km size range. Control of dynamic motion and static shape by actively stiffened structures is needed in order to permit future earth and space science experiments with large antennas, telescopes, and solar arrays.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Critical parameters are the large size, high configuration accuracy, and dynamic pointing control capability needed for advanced antennas, telescopes, and solar arrays.

b. Benefitting structural systems are all non-optical earth science and deep space antennas greater than approximately 20-30 meters in diameter, optical telescopes greater than approximately three meters in diameter, and large solar cell arrays on the order of one kilometer in size.

c. Allows full realization of signal gathering potential of large antennas and telescopes, high efficiency of space platforms and improved structural efficiency of large solar cell arrays.

d. In-orbit test of a controlled-configuration, continuously-pointable, highly-flexible antennas will demonstrate ultimately required capability. Ground tests on highly-flexible, scaled antenna models will provide assistance in technology development but will not demonstrate technology readiness.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): ____________

Activity Controlled/Stiffened Structures

7. TECHNOLOGY OPTIONS:

For large solar arrays, improved solar cell efficiency and orbits close to the sun may relax size requirements to some degree. For large antennas and telescopes, improved sensor sensitivity may allow smaller diameters for some application. Improved erectable and deployable structures technology may relax requirements for controls on some structures.

8. TECHNICAL PROBLEMS:

a. Lar' numbe. f modes which must be predicted and controlled.
b. Low frequency band of control system.
c. Control load transmission through weak structures.
d. Control of comples, closely-space, and non-linearly coupled modes.
e. Solar wind, gravity gradient, aerodynamic drag loads, etc.

9. POTENTIAL ALTERNATIVES:

There are no potential alternates except large lightweight, stiff structures, a technology which is not believed amenable to currently envisioned needs.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Control theory structural analysis methods, antenna design, sensor technology.

FUTURE PAYLOAD TECHNOLOGY NO. ______

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______

CATEGORY Structures and Dynamics

2. TITLE Actively controlled/Stiffened Structure Feasibility Test

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	5	7

Actively-controlled, highly-flexible structures are needed in order to meet future earth and space observation needs. Control of configuration accuracy on 100m- 0Km antennas and other large structures to one part in 10,000 with passive structures will be difficult within the 1985-2000 time frame.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1990

PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Allows large structures beyond passive structure capability for high resolution earth and space observation thus extending capability by an order of magnitude or more.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Number of required controls may be high thus increasing probability of failure, complexity of electronics, structures and controls interaction technology.

REQUIRED SUPPORTING TECHNOLOGIES Control theory, flight control equipment, sensors, loads definition

7. REFERENCE DOCUMENTS/COMMENTS ______

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TITLE Actively Controlled/Stiffened Structures

NO.

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Very flexible antenna of approximately 5m diameter with actively-augmented shape control and attitude control capabilities.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Deploy, activate controls, determine accuracy of shape and nature of deviations during pointing and operation

BENEFIT OF SPACE TEST: Develop technology for much larger (100m or greater diameter) antennas and other large space structures

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Ground test will not satisfy technology requirement

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____